

BRUSHLESS RESOLVER AND ITS CONSTRUCTING METHOD

Technical Field

The present invention relates to a brush-less resolver, and more particularly, to a brush-less resolver capable of reducing cost and obtaining arbitrary axial double angle in a new structure with no transformer section.

5 Background Art

A resolver, one of rotation position detectors, detects a rotation angle of a rotary machine using a phenomenon that when a coil on the excitation side is excited by an AC voltage, the phase or amplitude of an AC output voltage induced on a coil on the output side is changed depending on a rotation angle.

10 The principle of operation is common to that of a transformer, but the resolver differs from the transformer in that the iron core of the transformer is divided into a rotor and stator. The resolver can be used even in a high-temperature, high-vibration environment and is trouble-free, further resistant to noise and widely used as a detector for equipment requiring high-level reliability.

15 Of resolvers, a brush-less resolver generally uses a rotary transformer instead of a conventional brush and slip ring as means for transmitting a signal to the rotor.

Figure 7 shows a half section illustrating the structure of a conventional brush-less resolver. In the figure, the conventional brush-less resolver is
20 mainly constructed of a detection section (hereinafter referred to as "resolver section") including a stator made up of a stator resolver iron core 131 and a stator resolver coil 132, and a rotor made up of a rotor resolver iron core 141 and a rotor resolver coil 142, a stator transformer made up of a stator transformer 151 and stator transformer coil 152, and a rotary transformer

(hereinafter referred to as "transformer section") made up of a rotor transformer rotor transformer 161 and a rotor transformer coil 162.

That is, the brush-less resolver is mainly constructed of a resolver section which obtains a voltage according to a rotation angle and a transformer
5 section whose main purpose is to transmit signals to the rotor and when this is seen from a manufacturing aspect, the conventional brush-less resolver uses a cylindrical cutting transformer for the transformer section and uses a laminated iron core subjected to lamination machining for the resolver section, and in this way different components are used for various sections to manufacture the
10 brush-less resolver, requiring the corresponding manufacturing cost and number of steps.

Furthermore, when the brush-less resolver is seen from the functional aspect, the stator transformer, rotor transformer, rotor iron core and stator iron core constitute a magnetic circuit, the transformer section made up of the stator
15 transformer and rotor transformer carries only the function of transmitting a resolver excitation signal from the stator side to the rotor side in a non-contact manner, and the resolver section made up of the rotor iron core and resolver iron core has the original function of the resolver, that is, modulation of a resolver excitation signal corresponding to the rotation angle. Therefore, for
20 the conventional brush-less resolver, the transformer section does not contribute to the original function of the resolver.

As described above, the conventional brush-less resolver uses different components for the transformer section and resolver section, which results in a problem that it is difficult to reduce the manufacturing cost. Furthermore, while
25 the transformer section contributes to the realization of a brush-less structure of the resolver, the transformer section does not contribute to the modulation of a resolver excitation signal, but magnetic flux generated in the transformer section rather flows in the direction in which it is likely to interfere with the resolver section, which becomes one of causes of deterioration of the

performance when seen from the aspect of the rotation angle detection performance of the resolver.

On the other hand, from the standpoint of expansion of the resolver application field, there are demands for further improvement of rotation angle
5 detection accuracy, increase in the degree of freedom in selecting an axial double angle and increase in the degree of freedom in constructing the resolver in the brushless resolver.

In the case of a VR resolver, the rotor is constructed of only an iron core and has some effects in reductions of the number of parts and the number of
10 pieces, but in the expansion of the degree of freedom in selecting the axial double angle, it is impossible to realize a resolver with an axial double angle 1 using the VR resolver characterized in that an angle signal corresponding to one rotation is obtained by one rotation of the resolver because the rotor has a shape eccentric with respect to the rotation center.

15 Based on all that described above, it is a problem to be solved by the present invention to provide a brush-less resolver capable of eliminating the problems of the above described conventional technology, allowing a cost reduction and obtaining an arbitrary axial double angle including axial double angle 1. That is, in the manufacturing aspect, it is a problem to be solved by
20 the present invention to provide a brush-less resolver capable of reducing the number of parts and the number of pieces, reducing the cost, obtaining an arbitrary axial double angle including an axial double angle 1, increasing the degree of freedom of selecting an axial double angle, increasing the degree of freedom in an arbitrary resolver structure according to the use in the aspect of
25 detection accuracy and reducing interference between the magnetic circuit on the excitation side and the magnetic circuit on the output side in the aspect of performance.

Disclosure of the Invention

The present inventor has meticulously studied the problems described above and has come up with the present invention consequently by discovering that it is possible to solve the above described problem by adopting a new
5 structure without providing any transformer section provided for non-contact transmission of a conventional resolver excitation signal and reviewing a coil structure, etc., of the stator and rotor. That is, as means for solving the above described problems, the invention described in the patent claims in the present application is as follows.

10 (1) A brush-less resolver comprising excitation signal transmitting means for transmitting a resolver excitation signal from the stator side to the rotor side in a non-contact manner and a resolver section for modulating the resolver excitation signal corresponding to the rotation angle to be detected, wherein the resolver section also serves as the excitation signal transmitting
15 means.

(2) The brush-less resolver in (1), wherein the resolver section is constructed of a set of a rotor which has a slot and is made up of a rotor iron core provided with a coil (also referred to as "rotor coil") and a stator which has a slot and is made up of a stator iron core provided with a coil (also referred to
20 as "stator coil").

(3) The brush-less resolver in (2), wherein the stator coil comprises a stator excitation coil section which is a coil excited by an AC voltage for transmitting a resolver excitation signal to the rotor and a stator output coil section which is a coil for outputting a signal corresponding to the rotation to be
25 detected and appearing on the rotor, the stator excitation coil section and the stator output coil section are provided on the same single stator iron core, the rotor coil constitutes a rotor excitation coil which is a coil to receive a resolver excitation signal transmitted from the stator excitation coil section and a rotor output coil which is a coil to generate an output signal to the stator output coil

section, and the rotor excitation coil and the rotor output coil are provided on the same single rotor iron core.

(4) The brush-less resolver in (2) or (3), wherein at least one of the rotor shaft or case is omitted.

5 (5) The brush-less resolver in (3) or (4), wherein the stator comprises a stator excitation coil section which is a coil excited by an AC voltage for transmitting a resolver excitation signal to the rotor and a stator output coil section which is a coil for outputting a signal corresponding to the rotation angle to be detected and appearing on the rotor, at least one of the stator excitation
10 coil section or the stator output coil section is provided with coils with two phases; one having a sine-wave distribution and the other having a phase shifted by 90° (hereinafter referred to as "phases differing 90° from each other" or "phases differing from each other") and the rotor comprises a rotor coil section including a rotor excitation coil which is a coil to receive a resolver
15 excitation signal transmitted from the stator excitation coil section and a rotor output coil which is a coil to generate an output signal to the stator output coil section and the rotor excitation coil and the rotor output coil are coils with phases differing 90° from each other.

(6) The brush-less resolver in (5), wherein both the stator excitation
20 coil section and the stator output coil section are provided with coils with two phases differing 90° from each other and it is possible to select from among three types of signal processing system; 2-phase excitation 2-phase output, 1-phase excitation 2-phase output or 2-phase excitation 1-phase output by selecting a phase with which an excitation voltage is applied and a phase with
25 which an output signal is extracted.

(7) The brush-less resolver in any one of (3) to (6), wherein it is possible to obtain an angle signal with the number of revolutions N times one rotation of the resolver (N is an integer equal to or greater than 1 and an arbitrary number) by arbitrarily setting at least any one of combinations of the

number of slots of any one of the stator iron core or the rotor iron core, the number of pole pairs in an excitation function block made up of the stator excitation coil section and the rotor excitation coil and the number of pole pairs in an output function block made up of the stator output coil section and the rotor output coil.

(8) The brush-less resolver in any one of (5) to (7), wherein the relationship between the number of pole pairs m in the excitation function block and number of pole pairs n in the output function block is $m-n=1$ (where both m and n are positive integers and arbitrary numbers), opposite phases in phase rotation are set in the wiring between the rotor excitation coil and the rotor output coil in the rotor, thereby constructing a resolver with an axial double angle 1 capable of obtaining an angle signal corresponding to one rotation by one rotation of the resolver.

(9) The brush-less resolver in any one of (5) to (7), wherein the relationship between the number of pole pairs m in the excitation function block and number of pole pairs n in the output function block is $n-m=1$ (where both m and n are positive integers and arbitrary numbers), opposite phases in phase rotation are set in the wiring between the rotor excitation coil and the rotor output coil in the rotor, thereby constructing a resolver with an axial double angle 1 capable of obtaining an angle signal corresponding to one rotation by one rotation of the resolver in the opposite rotation direction.

(10) The brush-less resolver in any one of (5) to (7), wherein in order to prevent interference of magnetic flux between a resolver excitation signal in the excitation function block and an output signal in the output function block, the number of pole pairs m in the excitation function block is made different from the number of pole pairs n in the output function block (where, both m and n are positive integers and arbitrary numbers).

(11) A method of constructing the brush-less resolver in any one of (5) to (7), comprising a step of arbitrarily setting at least any one of combinations of

the number of slots of at least one of the stator iron core or the rotor iron core, the number of pole pairs in the excitation function block and the number of pole pairs in the output function block so as to construct a brush-less resolver capable of obtaining an angle signal with the number of revolutions N times one rotation of the resolver (where N is an integer equal to or greater than 1 and an arbitrary number).

(12) The method of constructing the brush-less resolver in any one of (5) to (7), wherein the number of pole pairs m in the excitation function block is made different from the number of pole pairs n in the output function block (where, both m and n are positive integers and arbitrary numbers) so as to prevent interference between an excitation signal and an output signal.

(13) The method of constructing the brush-less resolver in (12), wherein pole pairs are arranged so that the difference between the number of pole pairs m in the excitation function block and the number of pole pairs n in the output function block becomes 1 to thereby obtain an angle signal corresponding to one rotation by one rotation of the resolver, and when a resolver having an axial double angle 1 in the same rotation direction is obtained, the poles are constructed so that the relationship between m and n becomes $m-n=1$, whereas when a resolver which generates an angle signal whose rotation direction is opposite and whose amount of rotation corresponds to one rotation is obtained, the poles are arranged so that the relationship between m and n becomes $n-m=1$ and opposite phases in phase rotation are set in the wiring between the rotor excitation coil and the rotor output coil in the rotor (where both m and n are positive integers and arbitrary numbers).

(14) A brush-less resolver rotor, the rotor comprising an iron core having a slot provided with 2-phase coils, wherein the 2-phase coils are coils having phases differing 90° from each other for modulating a resolver signal.

(15) A coil structure for a brush-less resolver, the brush-less resolver having a resolver section comprising a stator excitation coil section made up of

2-phase coils, a stator provided with a coil which constitutes a stator output coil section and a rotor provided with coils having a total of two phases of a rotor excitation coil and rotor output coil, wherein when the number of pole pairs in the excitation function block made up of the stator excitation coil section and
 5 the rotor excitation coil is m ,

(A) when an excitation voltage is applied to both of the two phases in the stator excitation coil section, two signals E_3 and E_4 expressed by:

$$\text{[Expression]} \quad E_3 = K_1 E \sin(\omega t + m\theta), \quad E_4 = K_1 E \cos(\omega t + m\theta)$$

are obtained for the coils of the rotor,

10 (B) when an excitation voltage is applied to only one phase in the stator excitation coil section, two signals E_3 and E_4 expressed by:

$$\text{[Expression]} \quad E_3 = K_1 E_1 \cos(m\theta), \quad E_4 = K_1 E_1 \sin(m\theta)$$

are obtained for the coils of the rotor,

(where, suppose K_1 is a transformer ratio, E is an input signal, E_1 is an
 15 excitation signal, ω is an angular velocity, t is a time and θ is a rotation angle).

(16) The coil structure for a brush-less resolver in (15), wherein excitation signals E_1 , E_2 and output signals E_5 , E_6 of the brush-less resolver are expressed by,

(I) when the signal processing system is 2-phase excitation 2-phase
 20 output

$$\text{[Expression]} \quad E_1 = E \sin \omega t \quad \text{---} <1>$$

$$E_2 = E \cos \omega t \quad \text{---} <2>$$

$$E_5 = K E \sin\{\omega t + (m+n)\theta\} \quad \text{---} <5>$$

$$E_6 = K E \cos\{\omega t + (m+n)\theta\} \quad \text{---} <6>$$

25 where when the wiring between the input and output coils in the rotor is changed and the phase rotation is changed, the output signals are expressed by,

[Expression]

$$E_5 = K E \sin\{\omega t + (m-n)\theta\} \quad \text{---} <7>$$

$$E_6 = KE \cos\{\omega t + (m-n)\theta\} \text{ ---- } <8>$$

(II) when the signal processing system is a 1-phase excitation 2-phase output, the output signals are expressed by,

$$[\text{Expression}] \quad E_1 = E \sin \omega t \text{ ---- } <1>$$

$$5 \quad E_5 = KE_1 \cos\{(m+n)\theta\} \text{ ---- } <11>$$

$$E_6 = KE_1 \sin\{(m+n)\theta\} \text{ ---- } <12>$$

where when the wiring between the input and output coils in the rotor is changed and the phase rotation is changed, the output signals are expressed by,

$$10 \quad [\text{Expression}]$$

$$E_5 = KE_1 \cos\{(m-n)\theta\} \text{ ---- } <13>$$

$$E_6 = KE_1 \sin\{(m-n)\theta\} \text{ ---- } <14>$$

(III) when the signal processing system is a 2-phase excitation 1-phase output, the output signals are expressed by,

$$15 \quad [\text{Expression}] \quad E_1 = E \sin \omega t \text{ ---- } <1>$$

$$E_2 = E \cos \omega t \text{ ---- } <2>$$

$$E_5 = KE \sin\{\omega t + (m+n)\theta\} \text{ ---- } <17>$$

where when the wiring between the input and output coils in the rotor is changed and the phase rotation is changed, the output signals are expressed by,

20

$$[\text{Expression}]$$

$$E_5 = KE \sin\{\omega t + (m-n)\theta\} \text{ ---- } <18>$$

(where, suppose K is a transformer ratio, E is an input signal, ω is an angular velocity, t is a time, θ is a rotation angle, m is the number of pole pairs in the excitation function block and n is the number of pole pairs in the output function block).

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That is, in order to solve the problem with a cost reduction, the present invention provides means for not providing the transformer section which is provided for non-contact transmission of a conventional resolver excitation

signal, adopting new structures as the coil structures of the stator and rotor to obtain an arbitrary axial double angle including the axial double angle 1 and adopting new structures as the coil structures of the stator and rotor to reduce interference between the magnetic circuit on the excitation side and the magnetic circuit on the output side.

That is, the present invention realizes a cost reduction by not using the rotary transformer in the brush-less resolver and constructing the resolver using a combination of the rotor iron core having a slot and the stator iron core. Furthermore, the present invention provides each iron core with 2-phase coils having phases differing 90° from each other and changes the combination of the rotation angles of the excitation coil and output coil, the numbers of slots of the rotor iron core and stator iron core, and can thereby obtain an arbitrary axial double angle including the axial double angle 1. Since the axial double angle is determined by the number of slots and coil structure, the shape of the rotor iron core is not limited by the axial double angle and it is possible to construct a resolver with the axial double angle 1 without constructing the rotor iron core in a disadvantageous shape such as eccentricity which cannot be adopted from the standpoint of the structure of the resolver.

Brief Description of the Drawings

Figure 1 is a half section showing a structure of brush-less resolver according to the present invention;

Figure 2 is a circuit diagram showing a structure of a brush-less resolver of the present invention, Figure 2(a) is a connection diagram showing structures of the stator 3 and rotor 4 and Figure 2(b) is a connection diagram divided into blocks of the excitation function and output function as the resolver;

Figure 3 is a circuit diagram showing a structure of the brush-less resolver of the present invention when a signal processing system with 2-phase excitation 2-phase output is adopted, Figure 3(a) is a connection diagram

showing structures of the stator and rotor and Figure 3(b) is a connection diagram divided into blocks of the excitation function and output function as the resolver;

Figure 4 is a circuit diagram showing a structure of the brush-less resolver of the present invention when a signal processing system with 1-phase excitation 2-phase output is adopted, Figure 4(a) is a connection diagram showing structures of the stator and rotor and Figure 4(b) is a connection diagram divided into blocks of the excitation function and output function as the resolver;

Figure 5 is a circuit diagram showing a structure of the brush-less resolver of the present invention when a 2-phase excitation 1-phase output signal processing system is adopted, Figure 5(a) is a connection diagram showing structures of the stator and rotor and Figure 5(b) is a connection diagram divided into blocks of the excitation function and output function as the resolver;

Figure 6 is a graph showing a relationship between the axial angle measured by the brush-less resolver having the structure according to Embodiment 3 and output signal level ($m=8$, $n=7$, in the case of opposite phase rotations); and

Figure 7 is a half section of a conventional brush-less resolver.

The following are descriptions of symbols used:

1 ... Shaft, 2 ... Case, 3 ... Stator, 4 ... Rotor, 8 ... Lead wire, 10 ... Brush-less resolver, 33 ... Stator iron core, 34 ... Stator coil, 43 ... Rotor iron core, 44 ... Rotor coil, 341 ... Stator excitation coil section, 342 ... Stator output coil section, 441 ... Rotor excitation coil, 442 ... Rotor output coil, 3411, 3412, 3425, 3426 ... Stator coil, BR ... Excitation function block, BS ... Output function block, E_1 , E_2 ... Excitation voltage, E_5 , E_6 ... Output voltage

Best Mode for Carrying Out the Invention

With reference now to the attached drawings, embodiments of the present invention will be explained in detail below. Components having the same functions will be explained with the same reference numerals assigned including Figure 7 related to the above described conventional art.

Figure 1 is a half section showing a structure of brush-less resolver according to the present invention. In the figure, a brush-less resolver 10 of the present invention is mainly constructed of excitation signal transmitting means for transmitting a resolver excitation signal from a stator 3 side to a rotor 4 side in a non-contact manner and a resolver section 7 for modulating the resolver excitation signal corresponding to the rotation angle, with the resolver section 7 also serving as the excitation signal transmitting means. The resolver section 7 can be constructed of a set of a rotor 4 which has a slot and is made up of a rotor iron core 43 provided with a coil (hereinafter referred to as "rotor coil") 44 and a stator 3 which has a slot and is made up of a stator iron core 33 provided with a coil (hereinafter referred to as "stator coil") 34.

That is, the brush-less resolver of the present invention is not provided with any transformer section for non-contact transmission of a resolver excitation signal and is mainly constructed of only the resolver section 7 for modulating a resolver excitation signal corresponding to the rotation angle.

In the figure, the stator coil 34 is constructed of a stator excitation coil section 341 (not shown, see Figure 2) which is a coil excited by an AC voltage for transmitting a resolver excitation signal to the rotor 4 and a stator output coil section 342 (not shown, see Figure 2) which is a coil for outputting a signal appearing on the rotor 4 corresponding to the rotation to be detected and the stator excitation coil section 341 and the stator output coil section 342 can be provided on the same single stator iron core 33. On the other hand, the rotor coil 44 is constructed of a rotor excitation coil 441 (not shown, see Figure 2) which is a coil for receiving a resolver excitation signal transmitted from the

stator excitation coil section 341 and a rotor output coil 442 (not shown, see Figure 2) which is a coil for generating an output signal to the stator output coil section 342, and the rotor excitation coil 441 and the rotor output coil 442 can also be provided on the same rotor iron core 43. Both the stator iron core 33 and the rotor iron core 43 can be manufactured by presswork.

In the figure, the brush-less resolver of the present invention has a basic structure including the stator 3 made up of the stator iron core 33 and stator coil 34, further including the rotor 4 made up of the rotor iron core 43 and rotor coil 44 with the stator 3 and the rotor 4 constituting the resolver section 7 for modulating the resolver excitation signal corresponding to the rotation angle to be detected, and further including a rotor shaft 1 on which the rotor 4 is provided, a lead wire 8 connected to the stator coil 34 and a case 2 for housing the stator 3 and the rotor 4.

However, the present invention can also adopt a structure without providing at least one of the rotor shaft 1 or the case 2. That is, as long as the above described resolver structure is adopted, the brush-less resolver of the present invention can be constructed without providing the rotor shaft 1 or without housing the resolver section in the case 2 or with none of the rotor shaft 1 and the case 2.

In Figure 1, the brush-less resolver of the present invention is constructed as described above, and therefore non-contact transmission of a resolver excitation signal from the stator 3 side to the rotor 4 side is carried out not by the rotary transformer but by the resolver section 7 and modulation of the resolver excitation signal corresponding to the rotation angle to be detected is also carried out by the resolver section 7. The resolver section 7 can be constructed of a set of the rotor 4 which has a slot and is made up of the rotor iron core 43 provided with the stator coil 44 and the stator 3 which has a slot and is made up of the stator iron core 33 provided with the rotor coil 34, and can thereby simplify the resolver structure and reduce the manufacturing cost.

In the figure, the stator excitation coil section 341 (not shown, see Figure 2) which constitutes the stator coil 34 is excited by an AC voltage and a resolver excitation signal is transmitted to the rotor 4. Furthermore, a signal appearing on the rotor 4 corresponding to the rotation angle to be detected is
 5 output to the stator output coil section 342 (not shown, see Figure 2) which also constitutes the stator coil 34.

That is, an AC voltage is applied to the stator excitation coil section 341 (not shown, see Figure 2), magnetic flux thereby produced excites a voltage and produces a current on the rotor excitation coil 441 (not shown, see Figure
 10 2) which will be described later and which constitutes a magnetic circuit and the rotor output coil 442 (not shown, see Figure 2) which will be described later and which constitutes a circuit therewith produces and outputs magnetic flux, which causes a voltage corresponding to the rotation angle to be detected to be
 15 output to the stator output coil 341 (not shown, see Figure 2) which constitutes a magnetic circuit therewith and causes an electric signal to be generated.

Since the stator excitation coil section 341 and the stator output coil section 342 can be provided on the same single stator iron core 33, it is possible to reduce the number of parts to a minimum level in the manufacturing steps and reduce the manufacturing cost.

20 On the other hand, the rotor excitation coil 441 (not shown, see Figure 2) which constitutes the rotor coil 44 receives a resolver excitation signal transmitted from the stator excitation coil section 341. Furthermore, the rotor output coil 442 (not shown, see Figure 2) which also constitutes the rotor coil 44 generates an output signal at the stator output coil section 342.

25 That is, an AC voltage is applied to the stator excitation coil section 341 (not shown, see Figure 2) and magnetic flux thereby generated excites a voltage and produces a current on the rotor excitation coil 441 (not shown, see Figure 2) which constitutes a magnetic circuit and the rotor output coil 442 (not shown, see Figure 2) which constitutes a circuit therewith generates and

outputs magnetic flux, which causes a voltage corresponding to the rotation angle to be detected to be output to the stator output coil 341 (not shown, see Figure 2) which constitutes a magnetic circuit therewith and causes an electric signal to be generated.

- 5 The rotor excitation coil 441 and the rotor output coil 442 can be provided on the same single stator iron core 43, and therefore it is possible to reduce the number of parts to a minimum level in the manufacturing steps and reduce the manufacturing cost.

- 10 In the figure, the brush-less resolver of the present invention is not provided with at least one of the rotor shaft 1 or the case 2, that is, as long as the above described resolver structure is adopted, the brush-less resolver of the present invention can be constructed without providing the rotor shaft 1 or without housing the resolver section in the case 2 or with none of the rotor shaft 1 and the case 2, and can thereby reduce the number of parts, the number of
15 pieces and reduce the manufacturing cost.

- In Figure 1, the brush-less resolver has a structure without any transformer section, and therefore interference of the magnetic circuit from the transformer section to the resolver section, which has been the problem of the conventional brush-less resolver is eliminated and the resolver performance is
20 stabilized.

- Figure 2 is a circuit diagram showing a structure of the brush-less resolver 10 of the present invention, Figure 2(a) is a connection diagram showing structures of the stator 3 and rotor 4 and Figure 2(b) is a connection diagram divided into blocks of the excitation function and output function as the
25 resolver. Figure 2 also shows the structure of the 2-phase excitation 2-phase output resolver which will be described later, but the present invention will be explained here as the brush-less resolver having a basic structure also capable of selecting a 1-phase excitation 2-phase output or 2-phase excitation 1-phase

output signal processing system by adequately selecting the excitation side and output side.

In the brush-less resolver 10 of the present invention in Figure 2, the stator 3 is provided with a stator excitation coil section 341 which is a coil
 5 excited by an AC voltage for transmitting a resolver excitation signal to the rotor 4 and a stator output coil section 342 which outputs a signal appearing on the rotor 4 corresponding to the rotation to be detected and at least one of the stator excitation coil section 341 or the stator output coil section 342 is constructed as one having coils with two phases differing 90° from each other.
 10 According to the present invention, both the stator excitation coil section 341 and the stator output coil section 342 can be constructed as having coils with two phases differing from each other with respect to the rotation angle.

On the other hand, in the figure, the rotor 4 has a rotor coil section 44 made up of a rotor excitation coil 441 which is a coil for receiving the resolver
 15 excitation signal transmitted from the stator excitation coil section 341 and a rotor output coil 442 which is a coil for generating an output signal to the stator output coil section 342, and the rotor excitation coil 441 and the rotor output coil 442 are constructed so as to be coils having two phases differing 90° from each other.

20 In the figure, both the stator excitation coil section 341 and the stator output coil section 342 have coils 3411 and 3412, and 3425 and 3426 with two phases differing from each other with respect to the rotation angle and can be constructed so as to be able to select from three types of signal processing system; 2-phase excitation 2-phase output, 1-phase excitation 2-phase output
 25 or 2-phase excitation 1-phase output by selecting a phase for applying an excitation voltage and a phase for extracting an output signal.

The brush-less resolver of the present invention in the figure can be constructed so as to be able to obtain an angle signal with the number of revolutions N times with respect to one rotation of the resolver by arbitrarily

setting any one of the number of slots, number of pole pairs in the excitation function block BR or the number of pole pairs in the output function block BS from a combination of the number of slots of the iron core of at least one of the stator iron core 33 or the rotor iron core 43, number of pole pairs in the

5 excitation function block BR made up of the stator excitation coil section 341 and the rotor excitation coil 441 and number of pole pairs in the output function block BS made up of the stator output coil section 342 and the rotor output coil 442. Here, N is an integer equal to or greater than 1 (natural number) and an arbitrary number.

10 In Figure 2, the brush-less resolver of the present invention is constructed as described above, and therefore the stator excitation coil section 341 of the stator 3 is excited by an AC voltage, which causes a resolver excitation signal to be transmitted to the rotor 4 and causes the stator output coil section 342 to output a signal appearing on the rotor 4 corresponding to the
15 rotation to be detected.

That is, an AC voltage is applied to the stator excitation coil section 341, the magnetic flux thereby generated excites a voltage and produces a current on the rotor excitation coil 441 which constitutes a magnetic circuit, the rotor output coil 442 which constitutes a magnetic circuit therewith generates and
20 outputs magnetic flux, which causes a voltage corresponding to the rotation angle to be detected to be output to the stator output coil 341 which constitutes a magnetic circuit therewith and causes an electric signal to be generated.

Any one of the stator excitation coil section 341 or the stator output coil section 342 has coils with two phases differing 90° from each other. According
25 to the present invention, both the stator excitation coil section 341 and the stator output coil section 342 can have their respective coils with two phases (coils 3411 and 3412 for the stator excitation coil section 341, and coils 3425 and 3426 for the stator output coil section 342) differing 90° from each other,

and can thereby obtain excitation voltages with two different phases and output voltages with two different phases.

On the other hand, in the rotor 4 in the figure, the rotor excitation coil 441 receives a resolver excitation signal transmitted from the stator excitation coil section 341 and the rotor output coil 442 generates an output signal to the stator output coil section 342.

That is, an AC voltage is applied to the stator excitation coil section 341, the magnetic flux thereby generated excites a voltage and generates a current on the rotor excitation coil 441 which constitutes a magnetic circuit, the rotor output coil 442 which constitutes a circuit therewith generates and outputs magnetic flux, which causes a voltage corresponding to the rotation angle to be detected to be output to the stator output coil 341 which constitutes a magnetic circuit therewith and causes an electric signal to be generated.

The rotor excitation coil 441 and the rotor output coil 442 can have their respective coils having two phases differing 90° from each other, and can thereby obtain voltages with two different phases.

Therefore, the stator 4 selects a phase for applying an excitation voltage and a phase for extracting an output signal, and can thereby select from among three types of signal processing system; 2-phase excitation 2-phase output, 1-phase excitation 2-phase output or 2-phase excitation 1-phase output.

Furthermore, at least one of the number of slots, number of pole pairs in the excitation function block BR or number of pole pairs in the output function block BS is arbitrarily set and an angle signal with the number of revolutions N times with respect to one rotation of the resolver is obtained. That is, the number of slots of the stator iron core 33, number of slots of the rotor iron core 43, structure of the excitation coil in the excitation function block BR and the structure of the output coil in the output function block BS are arbitrarily set, and a necessary axial double angle is set. This increases the degree of freedom in selecting the axial double angle and results in an increase in the

degree of freedom of the resolver structure and design. Here, N is an integer equal to or greater than 1 (natural number) and an arbitrary number.

The brush-less resolver of the present invention in the figure has a relationship of $m-n=1$ between the number of pole pairs m in the excitation function block BR and number of pole pairs n in the output function block BS, that is, the number of pole pairs m in the excitation function block BR is set to be larger than the number of pole pairs n in the output function block BS by 1 and the wiring of the rotor excitation coil 441 and the wiring of the rotor output coil 442 in the rotor 4 can be set so as to have opposite phases in phase rotation and realize a resolver with axial double angle 1 capable of obtaining an angle signal corresponding to one rotation by one rotation of the resolver.

Furthermore, it is also possible to construct a resolver having a relationship of $n-m=1$ between the number of pole pairs m in the excitation function block BR and number of pole pairs n in the output function block BS, that is, the number of pole pairs m in the excitation function block BR is set to be smaller than the number of pole pairs n in the output function block BS by 1 and the wiring of the rotor excitation coil 441 and the wiring of rotor output coil 442 in the rotor 4 can be set so as to have opposite phases in phase rotation and realize a resolver with axial double angle 1 capable of obtaining an angle signal whose amount of rotation corresponds to one rotation by one rotation of the resolver.

In the brush-less resolver of the present invention in the figure, in order to prevent interference of magnetic flux between the resolver excitation signal in the excitation function block BR and the output signal in the output function block BS, it is possible to adopt a structure in which the number of pole pairs m in the excitation function block BR is made different from the number of pole pairs n in the output function block BS.

Next, an example of the structure of the brush-less resolver of each signal processing system will be explained based on the basic structure of the above described brush-less resolver of the present invention.

Figure 3 is a circuit diagram showing a structure of the brush-less resolver of the present invention when a signal processing system with 2-phase excitation 2-phase output is adopted, Figure 3(a) is a connection diagram showing structures of the stator and rotor and Figure 3(b) is a connection diagram divided into blocks of the excitation function and output function as the resolver. In this structure, the stator is constructed of a stator excitation coil a (m pole pairs) and stator output coil c (n pole pairs), while the rotor is constructed of a rotor excitation coil b (m pole pairs) and rotor output coil d (n pole pairs). E_1 , E_2 are excitation signals and E_5 , E_6 are output signals. Their theoretical expressions are as shown in <1> to <6> of Expression 1. In the expressions, K , K_1 , K_2 are transformer ratios, ω is an angular velocity (rad/s), t is a time (s) and θ is a rotation angle (rad). The same will also apply to the following expressions.

[Expression 1]

$$E_1 = E \sin \omega t \text{ ---- } <1>$$

$$E_2 = E \cos \omega t \text{ ---- } <2>$$

$$\begin{aligned} E_3 &= K_1 E_1 \cos(m\theta) + K_1 E_2 \sin(m\theta) \\ &= K_1 E \sin \omega t \cos(m\theta) + K_1 E \cos \omega t \sin(m\theta) \\ &= K_1 E \sin(\omega t + m\theta) \text{ ---- } <3> \end{aligned}$$

$$\begin{aligned} E_4 &= -K_1 E_1 \sin(m\theta) + K_1 E_2 \cos(m\theta) \\ &= -K_1 E \sin \omega t \sin(m\theta) + K_1 E \cos \omega t \cos(m\theta) \\ &= K_1 E \cos(\omega t + m\theta) \text{ ---- } <4> \end{aligned}$$

$$\begin{aligned} E_5 &= K_2 E_3 \cos(n\theta) + K_2 E_4 \sin(n\theta) \\ &= K_1 K_2 E \sin(\omega t + m\theta) \cos(n\theta) + K_1 K_2 E \cos(\omega t + m\theta) \sin(n\theta) \\ &= K E \sin(\omega t + m\theta + n\theta) \\ &= K E \sin\{\omega t + (m+n)\theta\} \text{ ---- } <5> \end{aligned}$$

$$\begin{aligned}
E_6 &= -K_2 E_3 \sin(n\theta) + K_2 E_4 \cos(n\theta) \\
&= -K_1 K_2 E \sin(\omega t + m\theta) \sin(n\theta) + K_1 K_2 E \cos(\omega t + m\theta) \cos(n\theta) \\
&= K E \cos(\omega t + m\theta + n\theta) \\
&= K E \cos\{\omega t + (m+n)\theta\} \text{ ---- } <6>
\end{aligned}$$

- 5 That is, according to the signal processing system with 2-phase excitation 2-phase output, the output signals E_5 and E_6 obtained are signals whose phases are shifted by $(m+n)\theta$ from the phases of the excitation signals E_1 and E_2 .

Here, if the wiring between the input and output coils in the rotor is
 10 changed and the phase rotation is changed, the theoretical expressions can be expressed by <7>, <8> of Expression 2.

[Expression 2]

$$\begin{aligned}
E_5 &= K_2 E_3 \cos(n\theta) - K_2 E_4 \sin(n\theta) \\
&= K E \sin\{\omega t + (m-n)\theta\} \text{ ---- } <7> \\
15 \quad E_6 &= K_2 E_3 \sin(n\theta) + K_2 E_4 \cos(n\theta) \\
&= K E \cos\{\omega t + (m-n)\theta\} \text{ ---- } <8>
\end{aligned}$$

That is, in this case, according to the signal processing system with 2-phase excitation 2-phase output, the output signals E_5 and E_6 obtained are signals whose phases are shifted by $(m-n)\theta$ from the phases of the excitation
 20 signals E_1 and E_2 .

Figure 4 is a circuit diagram showing a structure of the brush-less resolver of the present invention when a signal processing system with 1-phase excitation 2-phase output is adopted, Figure 4(a) is a connection diagram showing structures of the stator and rotor and Figure 4(b) is a connection
 25 diagram divided into blocks of the excitation function and output function as the resolver. In this structure, the stator is constructed of a stator excitation coil a (m pole pairs) and stator output coil c (n pole pairs), while the rotor is constructed of a rotor excitation coil b (m pole pairs) and rotor output coil d (n

pole pairs). E_1 is an excitation signal and E_5 , E_6 are output signals. The theoretical expressions are as shown in <11>, <12> of Expression 3.

[Expression 3]

$$\begin{aligned}
 E_1 &= E \sin \omega t \text{ ---- } <1> \\
 5 \quad E_3 &= K_1 E_1 \cos(m\theta) \text{ ---- } <9> \\
 E_4 &= K_1 E_1 \sin(m\theta) \text{ ---- } <10> \\
 E_5 &= K_2 E_3 \cos(n\theta) - K_2 E_4 \sin(n\theta) \\
 &= K_1 K_2 E_1 \{ \cos(m\theta) \cos(n\theta) - \sin(m\theta) \sin(n\theta) \} \\
 &= K E_1 \cos\{(m+n)\theta\} \text{ ---- } <11> \\
 10 \quad E_6 &= K_2 E_3 \sin(n\theta) + K_2 E_4 \cos(n\theta) \\
 &= K_1 K_2 E_1 \{ \cos(m\theta) \sin(n\theta) + \sin(m\theta) \cos(n\theta) \} \\
 &= K E_1 \sin\{(m+n)\theta\} \text{ ---- } <12>
 \end{aligned}$$

That is, according to the signal processing system with 1-phase excitation 2-phase output, the output signals E_5 and E_6 obtained have axial double angles $(m+n)$ times that of the excitation signal E_1 , that is, it is possible to obtain angle signals corresponding to $(m+n)$ rotations by one rotation.

Here, if the wiring between the input and output coils in the rotor is changed and the phase rotation is changed, the theoretical expressions are expressed by <13>, <14> of Expression 4.

20 [Expression 4]

$$\begin{aligned}
 E_5 &= K_2 E_3 \cos(n\theta) + K_2 E_4 \sin(n\theta) \\
 &= K E_1 \cos\{(m-n)\theta\} \text{ ---- } <13> \\
 E_6 &= -K_2 E_3 \sin(n\theta) + K_2 E_4 \cos(n\theta) \\
 &= K E_1 \sin\{(m-n)\theta\} \text{ ---- } <14>
 \end{aligned}$$

25 That is, in this case, according to the signal processing system with 1-phase excitation 2-phase output, the output signals E_5 and E_6 obtained have axial double angles $(m-n)$ times that of the excitation signal E_1 , that is, it is possible to obtain angle signals corresponding to $(m-n)$ rotations by one rotation.

Figure 5 is a circuit diagram showing a structure of the brush-less resolver of the present invention when a signal processing system with 2-phase excitation 1-phase output is adopted, Figure 5(a) is a connection diagram showing structures of the stator and rotor and Figure 5(b) is a connection diagram divided into blocks of the excitation function and output function as the resolver. In this structure, the stator is constructed of a stator excitation coil a (m pole pairs) and stator output coil c (n pole pairs), while the rotor is constructed of a rotor excitation coil b (m pole pairs) and rotor output coil d (n pole pairs). E_1 , E_2 are excitation signals and E_5 is an output signal. The theoretical expression is as shown in <17> of Expression 5.

[Expression 5]

$$\begin{aligned}
 E_1 &= E \sin \omega t \text{ ---- } <1> \\
 E_2 &= E \cos \omega t \text{ ---- } <2> \\
 E_3 &= K_1 E_1 \cos(m\theta) + K_1 E_2 \sin(m\theta) \\
 &= K_1 E \sin \omega t \cos(m\theta) + K_1 E \cos \omega t \sin(m\theta) \\
 &= K_1 E \sin(\omega t + m\theta) \text{ ---- } <15> \\
 E_4 &= -K_1 E_1 \sin(m\theta) + K_1 E_2 \cos(m\theta) \\
 &= -K_1 E \sin \omega t \sin(m\theta) + K_1 E \cos \omega t \cos(m\theta) \\
 &= K_1 E \cos(\omega t + m\theta) \text{ ---- } <16> \\
 E_5 &= K_2 E_3 \cos(n\theta) + K_2 E_4 \sin(n\theta) \\
 &= K_1 K_2 E \sin(\omega t + m\theta) \cos(n\theta) + K_1 K_2 E \cos(\omega t + m\theta) \sin(n\theta) \\
 &= K E \sin(\omega t + m\theta + n\theta) \\
 &= K E \sin\{\omega t + (m+n)\theta\} \text{ ---- } <17>
 \end{aligned}$$

That is, according to the signal processing system with 2-phase excitation 1-phase output, the output signal E_5 obtained is a signal whose phase is shifted by $(m+n)\theta$ from the phases of the excitation signals E_1 , E_2 .

Here, if the wiring between the input and output coils in the rotor is changed and the phase rotation is changed, the theoretical expression is expressed by <18> of Expression 6.

[Expression 6]

$$\begin{aligned} E_5 &= K_2 E_3 \cos(n\theta) - K_2 E_4 \sin(n\theta) \\ &= K E \sin\{\omega t + (m-n)\theta\} \text{ ---- } <18> \end{aligned}$$

That is, in this case, according to the signal processing system with 2-
 5 phase excitation 1-phase output, the output signal E_5 obtained is a signal
 whose phase is shifted by $(m-n)\theta$ from the phases of the excitation signals E_1 ,
 E_2 .

As described above, the brush-less resolver of the present invention can
 constitute a resolver according to various signal processing systems with 2-
 10 phase excitation 2-phase output, 1-phase excitation 2-phase output and 2-
 phase excitation 1-phase output, arbitrarily arrange their respective phase
 shifts, select a combination of the numbers of pole pairs m and n on the
 excitation side and output side, and thereby obtain angle signals N times (axial
 double angle N) with respect to the rotation angle θ . Furthermore, according to
 15 the number of slots of the iron core and a combination of m and n , it is possible
 to obtain a required N -time signal.

Furthermore, the brush-less resolver of the present invention can
 prevent interference between the excitation signal and output signal when the
 stator and rotor use the same iron core by making the number of pole pairs m
 20 in the excitation function block different from the number of pole pairs n in the
 output function block. Here, both m and n are positive integers and arbitrary
 numbers. The same will also apply below.

Furthermore, the brush-less resolver of the present invention constructs
 the poles in such a way that the difference between the number of pole pairs m
 25 in the excitation function block and number of pole pairs n in the output function
 block becomes 1 so as to obtain an angle signal corresponding to one rotation
 by one rotation of the resolver. To obtain a resolver with the axial double angle
 1 with the same rotation direction, the poles are constructed so that the
 relationship between the number of pole pairs m and n becomes $m-n=1$ in each

block. On the other hand, to obtain a resolver whose rotation direction is opposite and which generates an angle signal whose amount of rotation corresponds to one rotation, the poles are constructed so that the relationship between m and n becomes $n-m=1$ and the phases become opposite in phase rotation in the wiring between the rotor excitation coil and rotor output coil in the rotor.

The rotor in the brush-less resolver of the present invention is made up of the iron cores having slots provided with coils having two phases as shown above and the coils with two phases are constructed so as to have phases differing 90° from each other for modulating a resolver signal, which allows the above described brush-less resolver of the present invention to perform various types of signal modulation.

That is, the brush-less resolver of the present invention has a resolver section including a stator excitation coil section made up of coils with two phases, a stator provided with a coil constituting a stator output coil section, a rotor provided with coils having a total of two phases of the rotor excitation coil and rotor output coil. When the number of pole pairs in the excitation function block made up of the stator excitation coil and the rotor excitation coil is m , the following signal is generated in the rotor.

(A) When an excitation voltage is applied to both of two phases of the stator excitation coil section, the rotor coil can obtain two signal E_3 , E_4 expressed by:

$$[\text{Expression}] E_3 = K_1 E \sin(\omega t + m\theta), E_4 = K_1 E \cos(\omega t + m\theta)$$

(B) When an excitation voltage is applied to only one phase of the stator excitation coil section, the rotor coil can obtain two signal E_3 , E_4 expressed by:

$$[\text{Expression}] E_3 = K_1 E_1 \cos(m\theta), E_4 = K_1 E_1 \sin(m\theta)$$

Based on these signals, the output signal E_5 , E_6 in the stator output coil section are determined. The respective reference characters denote the same as those described above; K_1 denotes a transformer ratio, E and E_1 denote

excitation signals, ω denotes an angular velocity, t denotes a time and θ denotes a rotation angle.

Embodiments

The structure of the input/output coils of the brush-less resolver of the present invention in the case of 1-phase excitation 2-phase output (see Figure 4) will be shown below as an example. By changing the combination of m and n , an angle signal N (axial double angle N) times the rotation angle θ is obtained. The N -time signal is not limited to this example at this time, but it is possible to obtain the required N -time signal according to the number of slots of the iron core and the combination of m and n . In the following expressions, θ is a rotation angle, m is the number of pole pairs on the excitation side and n is the number of pole pairs on the output side.

1. When the number of pole pairs on the excitation side and the output side are $m=1$, $n=2$, respectively, the output signal is as shown by Expression 7. The axial double angle becomes 3 and a brush-less resolver is constructed which can obtain an angle signal corresponding to three rotations by one rotation.

[Expression 7]

When $m=1$, $n=2$, from Expressions <11>, <12>

$$\begin{aligned}
 E_1 &= E \sin \omega t \\
 E_5 &= K E_1 \cos \{(m+n)\theta\} \\
 &= K E_1 \cos \{(1+2)\theta\} \\
 &= K E_1 \cos 3\theta \\
 E_6 &= K E_1 \sin \{(m+n)\theta\} \\
 &= K E_1 \sin \{(1+2)\theta\} \\
 &= K E_1 \sin 3\theta
 \end{aligned}$$

2. When the numbers of pole pairs on the excitation side and the output side are $m=3$, $n=1$, the output signals are as shown in Expression 8.

The axial double angle becomes 4 and a resolver is constructed which can obtain an angle signal corresponding to four rotations by one rotation.

[Expression 8]

When $m=3$, $n=1$, from Expressions <11>, <12>

$$\begin{aligned}
 5 \quad E_1 &= E \sin \omega t \\
 E_5 &= K E_1 \cos \{(m+n)\theta\} \\
 &= K E_1 \cos \{(3+1)\theta\} \\
 &= K E_1 \cos 4\theta \\
 E_6 &= K E_1 \sin \{(m+n)\theta\} \\
 10 \quad &= K E_1 \sin \{(3+1)\theta\} \\
 &= K E_1 \sin 4\theta
 \end{aligned}$$

3. When the numbers of pole pairs on the excitation side and the output side are $m=8$, $n=7$ and when the phase rotation is opposite, the output signals are as shown in Expression 9. An axial double angle becomes 1 and a brush-less resolver is constructed which can obtain an angle signal corresponding to one rotation by one rotation.

[Expression 9]

When $m=8$, $n=7$ and when the phase rotation is opposite, from Expressions <13>, <14>,

$$\begin{aligned}
 20 \quad E_1 &= E \sin \omega t \\
 E_5 &= K E_1 \cos \{(m-n)\theta\} \\
 &= K E_1 \cos \{(8-7)\theta\} \\
 &= K E_1 \cos \theta \\
 E_6 &= K E_1 \sin \{(m-n)\theta\} \\
 25 \quad &= K E_1 \sin \{(8-7)\theta\} \\
 &= K E_1 \sin \theta
 \end{aligned}$$

4. When the numbers of pole pairs on the excitation side and the output side are $m=1$, $n=2$ and when the phase rotation is opposite, the output signals are as shown in Expression 10. A brush-less resolver is constructed

whose phase rotation is opposite and which can obtain an angle signal corresponding to one rotation by one rotation.

[Expression 10]

When $m=1$, $n=2$ and when the phase rotation is opposite, from

5 Expressions <13>, <14>,

$$E_1 = E \sin \omega t$$

$$E_5 = KE_1 \cos \{(m-n)\theta\}$$

$$= KE_1 \cos \{(1-2)\theta\}$$

$$= KE_1 \cos \theta$$

10 $E_6 = KE_1 \sin \{(m-n)\theta\}$

$$= KE_1 \sin \{(1-2)\theta\}$$

$$= -KE_1 \sin \theta$$

Figure 6 is a graph showing a relationship between the axial angle measured by the brush-less resolver having the structure according to Embodiment 3 and output signal level ($m=8$, $n=7$, in the case of opposite phase rotation). The graph shows that a brush-less resolver is constructed whose axial double angle is 1 and which can obtain an angle corresponding to one rotation by one rotation. In the figure, the unit of the axial angle shown on the horizontal axis is not rad but $^\circ$ (degree).

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Industrial Applicability

Being constructed as shown above, the present invention can reduce the manufacturing cost of a brush-less resolver and obtain an arbitrary axial double angle including axial double angle 1. That is, in the aspect of manufacturing, a simple structure that eliminates the need for any rotary transformer section can reduce the number of components, number of pieces and the number of manufacturing steps and reduce the manufacturing cost.

25

Furthermore, it is possible to obtain an arbitrary axial double angle including axial double angle 1 without taking a disadvantageous structure in the

shape of the iron core such as eccentricity and adopt an arbitrary resolver structure according to the application in aspects of detection accuracy and detection resolution, etc. That is, the degree of freedom in selecting axial double angles increases and it is possible to increase the degree of freedom in the resolver structure together with versatility of available signal processing systems.

In the aspect of performance, the structure without requiring any transformer section can solve the problem of interference between the magnetic circuit on the excitation side and the magnetic circuit on the output side.